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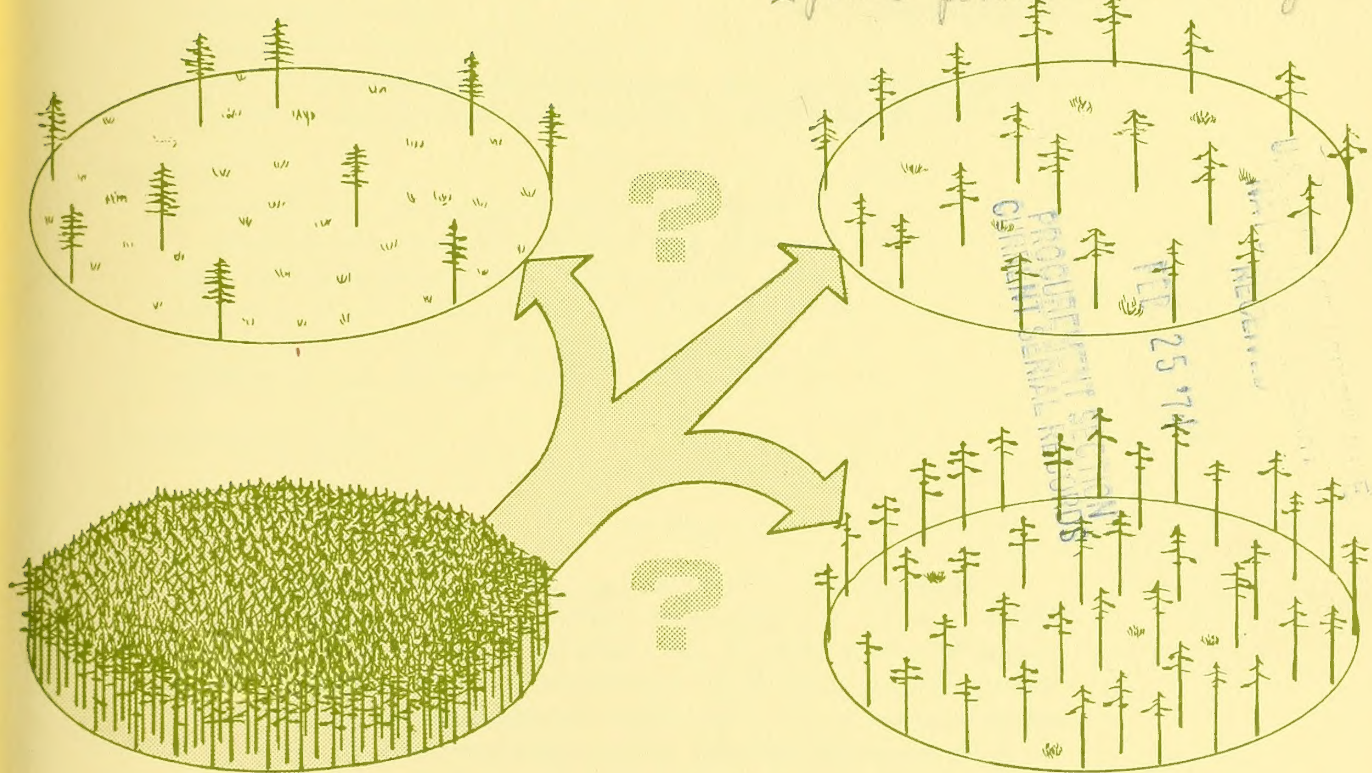
Economics of Thinning Stagnated Ponderosa Pine Sapling Stands in the Pine-Grass Areas of Central Washington



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ABSTRACT

Present net worth values earned by investments in precommercial thinning of stagnated ponderosa pine sapling stands are reported for three stocking levels. Ten timber management regimes are ranked by their returns from timber only, and 19 regimes are ranked according to their returns from timber and forage, with and without the allowable cut effect.

Keywords: Ponderosa pine, forestry business economics, thinning (trees), allowable cut effect, forage.

NOTICE

Research Paper PNW-144 has been revised to amend tables 2 and 3. The present net worths of the management regimes listed in tables 2 and 3 were obtained by subtracting the present net worth of the appropriate control stand from the present net worth of the various management regimes to show the marginal economic returns associated with the funds invested in precommercial thinning. The control stands should not have been listed in tables 2 and 3 in the original PNW-144. This revised version is issued to prevent any misinterpretation.

CONTENTS

INTRODUCTION

This paper reports the economic returns that can be earned by investing in precommercial thinning of stagnated ponderosa pine (*Pinus ponderosa*)[1] sapling stands. Returns from thinning to three stocking levels, with and without the allowable cut effect,[2] are published for the information of land managers, silviculturists, and those who are interested in management decisions to be made on the millions of acres of overstocked ponderosa pine stands in the Pacific Northwest. Ten timber management regimes are ranked according to their economic returns from timber only, and 19 regimes are ranked when both timber and forage produce revenue.

The major reason for this study is the large acreage that may benefit from the development of economic management guidelines for precommercially thinning stagnated stands of ponderosa pine saplings. According to Forest Survey records, several million acres of such stands in Oregon and Washington occur in two forms: the unmerchantable "doghair" stands, made up of many very slow-growing stems of about the same age and size, and the two-story stands, consisting of mature or overmature overstory and a dense understory of stems less than merchantable size. We are concerned here with stands less than rotation age without a mature overstory.

[1] Scientific names for grasses and sedges are according to Hitchcock (*8*); for forbs and shrubs, Hitchcock et al. (*9*); for trees, Little (*10*).

[2] The allowable cut effect is defined here as the immediate increase in today's allowable cut which is attributable to expected future increases in timber yields on regulated forests. This is the definition used by Schweitzer et al. (*16*).

The present trend toward wider spacing of trees in Pacific Northwest pine management is another reason for conducting this study. Barrett (*3*) has shown that in naturally occurring low density stands, 140 trees produced as much wood in 45 years as 460 trees produced on a similar site. However, the tree density that is the most compatible with other uses, plus being economically feasible, is still a subject for debate.

Finally, we must consider questions related to joint returns from timber and forage that result from precommercial thinning.

There are two distinct types of forest-grazing land: pine-grass and pine-shrub. Pine-grass areas are most common in central and eastern Washington, and pine-shrub areas are usually found in eastern Oregon. Our attention is focused on management regimes common to National Forests in the pine-grass areas.

Our objective is to determine which of several thinning schedules for stagnated ponderosa pine sapling stands produces the greatest economic returns, and this study is a start in the development of these guides. It is based on data for one site (a high Site V) in the pine-grass area of central Washington. The schedules differ in stocking, forage production, and the length (time) of management regime. Proper use of this study requires that the assumptions and constraints be kept firmly in mind.

Sensitivity analyses were conducted for a range of stumpage and forage prices and a variety of costs. However, the study results which are summarized in tables 2 and 3 reflect generally conservative cost estimates and liberal prices. Both of these tend to increase the estimated return on investment. Even so, all of our alternatives (when the allowable cut effect is not included) yield less than the guiding rate of return. You may want to compare your assumptions with ours and speculate on the extent to which your management activities should agree with our study findings.

PHYSICAL DESCRIPTION

THE TIMBER STAND

A ponderosa pine stand located on Washington State Department of Game lands in the upper Methow River Valley north of Winthrop, Washington, provided timber and forage data for the decade following a precommercial thinning in 1957. This stand originated from natural seeding about 1911 following logging and fire. Surviving trees of the original stand, unmerchantable at the time of logging, indicated an above average Site V (*13*).

Before thinning, the 47-year-old stand contained over 2,300 stems per acre (fig. 1). Trees averaged 3 inches in diameter and 17 feet in height. Growth was extremely slow. Individual trees added only 0.6 inch per decade to their diameter and 3.5 feet to their height. None of the maladies common to many ponderosa pine stands such as needle blight, root rot, or mistletoe were present. An occasional tree died from suppression, but generally the stand had settled into a state of stagnation. Fortunately, crowns of dominants were full and not dwarfed in relation to their bole as they would be in stands with higher densities, so prospects for increasing tree growth by thinning looked good. Since this stand is a good representative of the several million acres of overdense ponderosa pine stands in the Pacific Northwest, a study was initiated to test individual tree and stand performance under varied spacings (*1*).

Figure 1.—Unthinned ponderosa pine stand with over 2,300 stems per acre.

Four stand treatments--thinning to 250 trees per acre (average spacings of 13.2 feet), 125 trees per acre (average spacings of 18.7 feet), 62 trees per acre (average spacings of 26.4 feet), and no thinning--were tested. Each treatment was replicated three times. The wider spacings were chosen to define a limit on spacing so that the capacity of an acre to produce wood could be concentrated on as few trees as possible. After thinning to 125 trees per acre at age 47 years, diameter and height averaged 5 inches and 25.7 feet. This would correspond to an effective age[3] of about 25 years. Immediately after thinning to 62 trees per acre, diameter of trees averaged 5.8 inches. Ten years after thinning, they averaged about 9 inches with some 11.5-inch trees 50 feet tall, an encouraging departure from the stagnated stand shown in figure 1.

[3] Effective age as used here is defined as the number of years it would take a managed stand to grow to the average diameter of the crop trees plus the years necessary to recover from stagnation.

During the 10 years of observation on this study, thinning has stimulated diameter growth to produce a usable product (fig. 2) within a reasonable time. Trees at the widest spacing have added 3 inches to their diameter during the past decade, and trees spaced 13.2 and 18.7 feet have grown 1.8 and 2.5 inches, respectively (fig. 3). Comparable trees in unthinned plots continue to grow at only a half or a third of those rates.

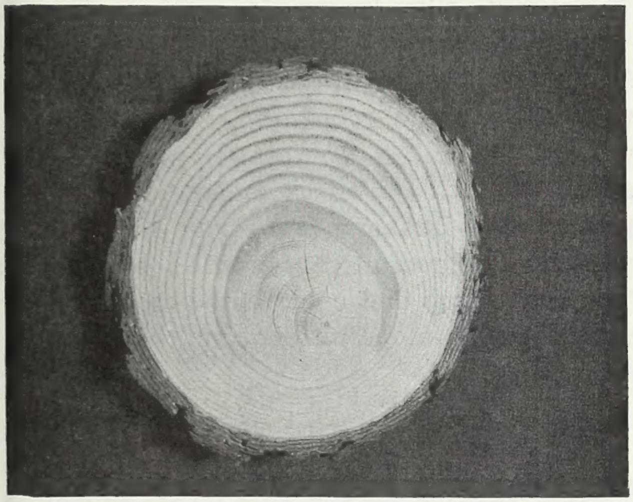


Figure 2.—Cross section cut from a released ponderosa pine.

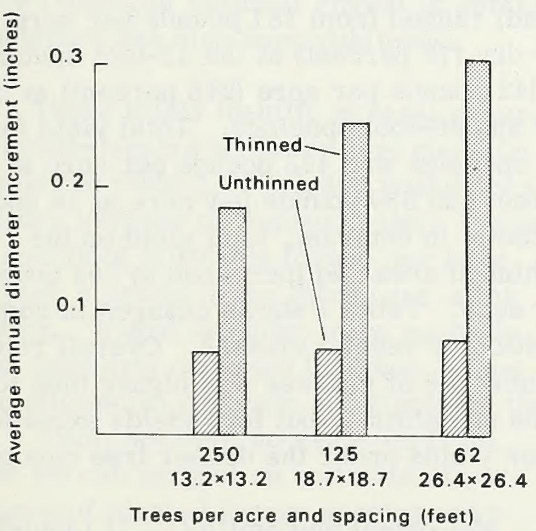


Figure 3.—Average annual diameter increment per tree in the thinned stand and average growth on a comparable number of trees in the unthinned stand during the 10 years following thinning.

During the 10 years, none of the thinned stands have produced as much wood fiber as the unthinned stand (fig. 4). However, there has been an increase in fiber production in thinned stands from the first 5-year period to the second; the growing-stock base is increasing so net cubic growth will probably equal or exceed unthinned stand production in the next decade or so. And most important, in the thinned stand, wood is being added to trees that will grow to usable sizes. In contrast, much of the wood growth in the unthinned stand will be added to trees that will either die or never reach merchantability.

GROUND COVER

The understory in these thickets of ponderosa pine is a sparse stand of spindly shrubs and scattered forbs and grasses (fig. 5). Total air-dry herbage production on the unthinned portion of the study area was about 117 pounds per

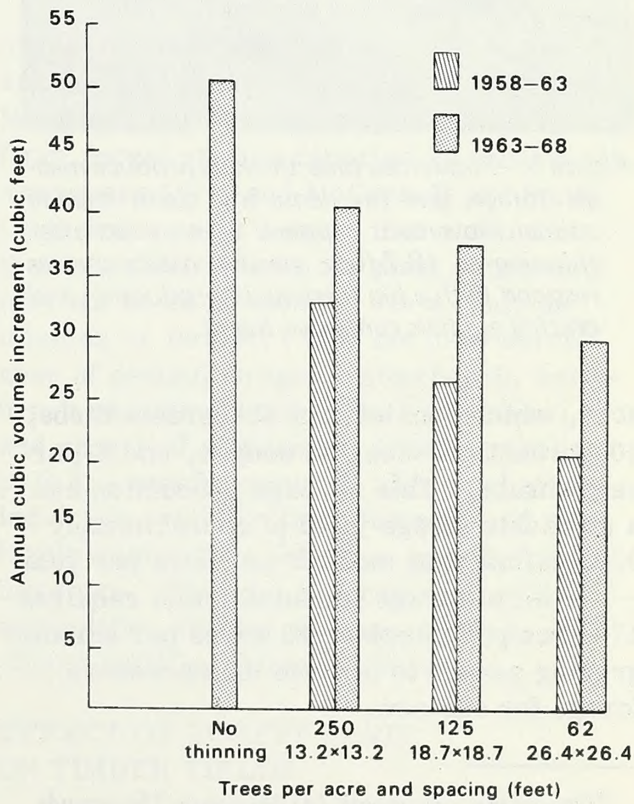


Figure 4.—Periodic average annual increment of unthinned stand and stands thinned to various densities.

Figure 5.—Ponderosa pine thickets produce meager forage, and the dense tree stems impede animal movement (upper). Seven years after thinning to 18.7-foot spacing, native species respond with a big increase in production and grazing animals can move freely.

acre, which consisted of 58-percent forbs, 40-percent grasses and sedges, and 2-percent shrubs. This herbage production has a utilizable forage yield of approximately 0.06 animal unit month[4] per acre per year --a level of forage production that requires 17 acres per month or 68 acres per summer grazing season to provide the necessary forage for one cow.

[4] One animal unit month (AUM) equals 730 pounds of air-dry forage for cattle (this is the amount of forage consumed by a 1,000-pound animal in 30.5 days).

Pinegrass (*Calamagrostis rubescens*), an acceptable forage species and the predominant grass in the area, accounted for 92 percent of the grass and sedge component with sedges (*Carex* spp.), needlegrass (*Stipa* spp.), beardless wheatgrass (*Agropyron inerme*), Idaho fescue (*Festuca idahoensis*), and prairie junegrass (*Koeleria cristata*) making up the balance. The forb component was dominated by balsamroot (*Balsamorhiza sagittata*), 71 percent; silky lupine (*Lupinus sericeus*), 11 percent; and pussytoes (*Antennaria* spp.), 5 percent. Lesser forbs included woollyweed (*Hieracium scouleri*), western yarrow (*Achillea lanulosa*), wayside gromwell (*Lithospermum ruderale*), purpledaisy fleabane (*Erigeron corymbosus*), and gland cinquefoil (*Potentilla glandulosa*). The only shrub that contributed measurable yields was antelope bitterbrush (*Purshia tridentata*).

As the trees are thinned, the understory vegetation responds with a substantial increase in production. After eight growing seasons, the net average increase due to thinning (total yield increase in thinned stands minus increase in unthinned control stand) ranged from 181 pounds per acre air-dry (79 percent) at the 13-foot spacing to 342 pounds per acre (246 percent) at the 19- and 26-foot spacings. Total yield for the spacings was 485 pounds per acre at 13 feet and 550 pounds per acre at 19 and 26 feet. In contrast, total yield on the unthinned area had increased to 192 pounds per acre. Table 1 shows changes in composition by vegetal classes. Overall rate of increase of grasses was higher than for forbs and shrubs, but forb yields exceeded grass yields under the denser tree canopies.

McConnell and Smith (*12, 13*) found that the increase in yield of herbaceous species began to level off after 8 years, and additional yield will probably be minor. On the other hand, bitterbrush, which is

Table 1.--Percent of composition in three vegetal classes after one and eight growing seasons after thinning ponderosa pine

Classes	Tree spacing treatments							
	Unthinned		13 feet		19 feet		26 feet	
	1958	1965	1958	1965	1958	1965	1958	1965
Grasses and sedges	40	35	50	40	67	55	67	52
Forbs	58	64	46	55	31	37	30	39
Shrubs	2	1	4	5	2	8	3	9

much slower to respond to tree thinning than the herbaceous species, continues its upward climb.

There are no published yield data on forage species planted in ponderosa pine thinnings. There is, however, an excellent summary by Schwendiman (*17*) of information gleaned from species adaptability trials on forested rangelands of the Northwest, including seedings made in forest burns. An article by McClure (*11*) on grass seedings in lodgepole pine burns on the Okanogan National Forest in central Washington has also been published.

These trials identify several grasses and grass-legume mixtures that could be expected to yield 1,000-1,400 pounds per acre dry herbage or approximately 1 animal unit month of utilizable forage per acre per year starting in the third year after seeding. Where seedings were made in areas formerly occupied by trees, trees were allowed to reinvade and dominate the site. Thus, we have no evidence from which we can project an estimate of persistence of planted forage species over time. Therefore, we assume that production of planted forage will not diminish over a 90- to 100-year pine rotation if the following conditions are met: (1) species are chosen with proper regard to site adaptability, (2) grazing is not permitted until the third year and then only at a rate that will not result in overgrazing, and (3) tree basal area is kept at 80 to 90 square feet per acre by periodic thinning.

EFFECT OF FORAGE ON TIMBER YIELDS

The interactions between timber overstories and vegetation understories are complex and not completely understood. However, our knowledge is growing rapidly from recent studies reported by Gordon (*7*), Youngberg (*20*), and McConnell and Smith (*13*), and we now suspect that a situation that is undesirable in one plant community may not be so in another. In a study on thinning by Barrett (*2*) in the pine-shrub area of central Oregon, bitterbrush, snowbrush ceanothus (*Ceanothus velutinus*), and greenleaf manzanita (*Arctostaphylos patula*) rapidly occupied additional growing space available from thinning and were highly competitive with tree growth for soil moisture. Thus the understory provided competition similar to removed trees and almost nullified thinning effects.

EFFECT OF FOREST PESTS ON TIMBER YIELDS

Timber yields are projected on the basis of results of a study in natural, dense, and unthinned control stands, and thinned natural stands with densities similar to the three used in this study.

We can predict the impact of disease and insects in dense unthinned stands that are protected from fire. We cannot, however, predict what will happen to thinned stands of ponderosa pine, because we have not had thinned stands long enough in the Pacific Northwest. Therefore, in this study, only anticipated mortality from insects in the unthinned stand are applied to projected yields. Yields are reduced according to the best available estimates of what would happen in this type of stand.[5]

The presence of dwarf mistletoe in pine stands in the Pacific Northwest has long been recognized and its impact on mature trees was recently quantified (*4*); however, the devastating impact on understory reproduction was recognized only recently (*18*). Past practice was the removal of infected overstory and sanitation of the understory by thinning and pruning. Results have been discouraging, so National Forest practice now is to harvest the infected overstory, destroy the infected understory, and plant new stock. The presence of dwarf mistletoe, then, would dictate that we start over with planted stock.

EXPERIMENT DESIGN AND METHODS

Three timber management regimes are proposed for the remainder of the present rotation for each of three stocking levels that result from different intensities of precommercial thinning at age 47. The first regime is a clearcut at age 77 years (30 years after the precommercial thinning). The second is a commercial thinning at age 77 years and a clearcut at age 97 years (50 years after the precommercial thinning). The third is a commercial thinning at age 77 years, a shelterwood cut at age 97 years, and an overstory removal at age 102 years (55 years after the precommercial thinning). Growth of this 47-year-old stand was projected forward in time using observed growth from age 47 to 57 and by applying growth observations from other studies for ages 57 to 102 years (*2, 3*).

These nine regimes assume no added investment in forage production. By assuming that forage is planted immediately after the precommercial thinning in each of the foregoing regimes, nine more regimes are created. A 19th regime involved clearcutting the stagnated stand immediately at age 47 (instead of precommercially thinning it) and planting a new stand. Three additional regimes on unthinned stagnated stands are to clearcut at age 77 years, to clearcut at 97 years, and to shelterwood cut at 97 years with an overstory removal at 102 years. These are the control regimes; they indicate what is expected of stagnated stands if no thinnings occur; and they are a base for comparison with the thinning regimes.

ECONOMIC MODEL

Present net worth (*PNW*) and internal rate of return (*IROR*) are two economic measures of investment efficiency. *PNW* is the present or discounted value of future benefits minus the present value of future costs. To determine the present value of a future cost or benefit, one must discount it to the present at some interest rate, i.

This may be expressed as: present value of a cost (PVc) equals the cost that occurs in year t, C_t, divided by $(1 + i)^t$. The interest rate is expressed in decimal form; or more simply, $PVc = C_t/(1 + i)^t$.

[5] As formulated by Sartwell (*14*).

Likewise, the present value of a return, PVr, is expressed as: $PVr = R_t/(1+i)^t$. Therefore, the PNW of the costs and returns that occur in year t is:

$$PNW = \frac{R_t}{(1+i)^t} - \frac{C_t}{(1+i)^t}.$$

It follows that the PNW of a series of costs and returns is represented as:

$$PNW = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$$

when n is the number of years in the investment series.

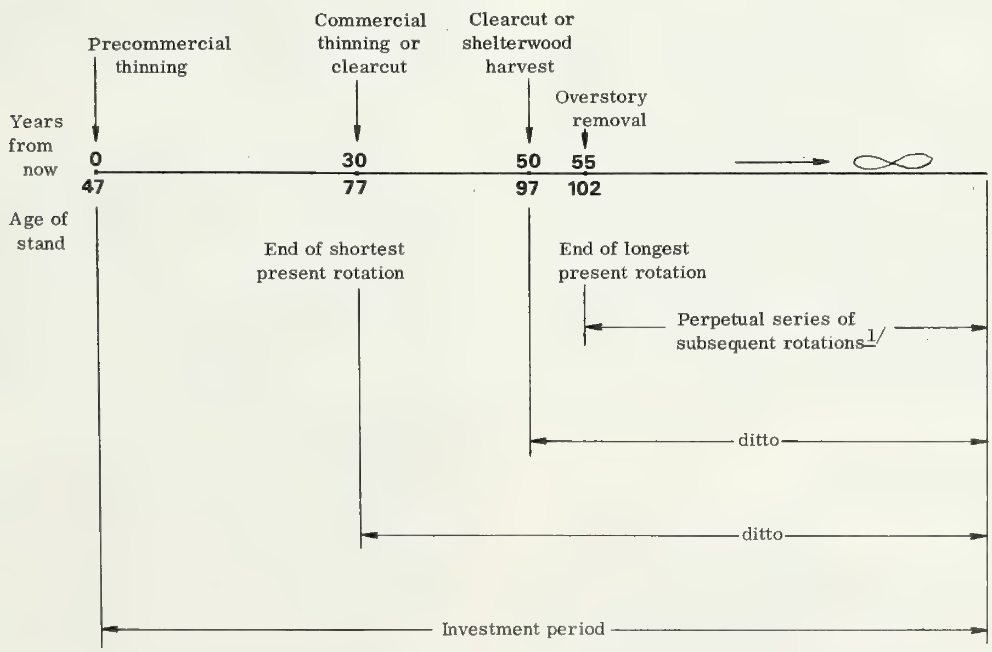
The $IROR$ is simply the interest rate which equates discounted returns to discounted costs, i.e., the rate that results in a PNW of zero. The $IROR$ is equal to i when:

$$\sum_{t=0}^{n} \frac{R_t}{(1+i)^t} = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}.$$

We calculated both the PNW and IROR for all the management regimes three times: once based on timber returns only, again for timber and forage returns, and finally for timber and forage returns including the allowable cut effect. We have ranked the management regimes by PNW since this criterion is more useful than IROR when the investment alternatives are mutually exclusive events (*19*).

Rotation ages of the present management regimes vary from 77 to 102 years. The present values of costs and returns are adjusted to put them on a common time basis. We accomplished this by arbitrarily assuming that the same (presumably optimal) management regime would be put into effect at the end of the present rotation for all management regimes and that it would be continued in perpetuity (see figure 6 for a schematic diagram of the investment period.)

Figure 6.—Schematic diagram of the investment period for the ponderosa pine thinning analysis.



[1/] The same (presumably optimal) management regime will go into effect at the end of *all* present rotations and continue in perpetuity.

The *PNW* of each management regime can be expressed as:

$$PNW = \left[\begin{array}{l}\text{Present value of returns -}\\ \text{present value of costs}\\ \text{generated during the years}\\ \text{remaining in the present}\\ \text{rotation}\end{array}\right] + \left[\begin{array}{l}\text{Present net worth of per-}\\ \text{petual series of subsequent}\\ \text{management regimes (begin-}\\ \text{ning 30 to 55 years in the}\\ \text{future)}\end{array}\right].$$

When an interest rate is used that approximates the rate charged to the Federal Government to borrow funds (the guiding rate of return), presently 5 to 6 percent, and the allowable cut effect is not included in the economic analysis, the *PNW* of all alternatives is negative. This means that the regimes with a negative *PNW* earned less than 5 percent.

In our analysis we are dealing with a constrained decision. We start with a 47-year-old stand that is essentially stagnated. Our alternatives are limited to either modifying the stand by thinning (including eradication of all stems) or leaving it unchanged. So we are dealing with marginal investments. We must calculate the incremental net cash flow associated with each thinning regime. This is accomplished by subtracting the *PNW* of the control stand from the *PNW* of each thinning regime. Costs that occurred in the previous 47 years of the present rotation are *sunk costs*. They are beyond our control; they are gone. Hence, they have no bearing on the decision at hand--what to do with the present stand to insure the greatest returns from this stand of timber from this point on.

ECONOMIC INPUT DATA CHARACTERISTICS

It is most convenient to discuss our economic input data by referring to two separate time periods: the present rotation and the perpetual series of future management regimes. The latter are expected to begin immediately upon conclusion of the present rotation. All input data were selected after consultation with forest administration (including field) personnel. Let's begin with the present rotation.

The precommercial thinning, which we assumed cost $22 per acre, reduced stocking from 2,300 stems to 250 stems per acre or less, depending on the management alternative. It also left a large volume of slash that required treatment to reduce fire danger and promote forage growth. Without treatment, fire danger remains high until the slash breaks down naturally, a process which requires several decades in this dry climate. In the meantime, the slash was a major obstacle to the free movement of domestic grazing animals. The slash also reduced forage production.

There are several ways to deal with the slash that results from the initial thinning of stagnated sapling stands. Fire danger can be reduced by mechanically crushing slash with a "Tomahawk" (5)--a brush-cutting tool mounted on the blade of a D-6[6] crawler tractor (fig. 7)--but this does little to promote forage growth. Machine piling and burning are more effective means of reducing slash and promoting forage growth but are also more expensive and may be judged esthetically displeasing. Use of a "Tomahawk" costs $15 to $22 per

[6] Use of trade names does not constitute endorsement by the U.S. Department of Agriculture.

Figure 7.—A "Tomahawk" mounted on a D-6 crawler tractor. This attachment weighs approximately 2,700 pounds and is useful for crushing slash and brush.

acre; and machine piling and burning, $30 to $60 per acre depending on stand density after thinning. The cost of both methods increases with increasing thinned stand density as more care and time are required to maneuver machines at the heavier stocking levels.

Other present rotation costs are: general administration, $2.30 per acre per year; timber sale administration, $0.165 per thousand board feet (covers that part of the timber sale costs not included in general administration costs); rodent control, $10 per acre (occurs once during a rotation, usually during the first year of regeneration); and, when appropriate, grass planting, $7.50 per acre (follows the slash removal operation after the precommercial thinning).

Now let's consider future management regimes. These regimes outline our best expectations of what timber harvest plans, including costs and revenues, will be. With clearcutting regimes, site preparation is the first cost of the rotation. We assumed a conservative $24 per acre for this cost. However, depending on topography and the volume of slash left on the ground from the previous harvest, it may cost as much as $50 to $60 per acre. Site preparation occurs immediately (year 0) in the first rotation. This is followed by the tree-planting operation ($20 per acre) and the rodent control treatment ($10 per acre) in the first year of the rotation. Two hundred trees are planted with an assumed survival rate of 80 percent.

A grass-legume mixture is planted ($7.50 per acre) in the first year. Two growing seasons pass before grazing is permitted. Each year a general administration cost of $2.30 per acre is charged. Basal area is held at 80 to 90 square feet per acre by commercial thinning at age 45, 60, and 75 years. A "Tomahawk" ($15 per acre) is used to reduce slash after each thinning. A timber sale administration cost of $0.165 per thousand board feet applies to commercial thinnings and final harvests.

Future shelterwood management regimes have similar costs except that no trees are planted and no site preparation is needed. Instead, slash removal ($26 per acre) follows the shelterwood cut to increase the success of natural seeding before overstory removal.

Soil disturbance from the shelterwood harvest and slash removal benefits natural seeding. A precommercial thinning ($8.50 per acre) at age 10 years reduces stocking to 160 stems per acre. All other costs for the future shelterwood regimes are the same as those listed for the future clearcut regimes.

All costs are varied in our analysis to determine the sensitivity of the final results to these cost assumptions.

Revenue from both future clearcut and shelterwood regimes are based on a range of stumpage prices including $20, $30, and $40 per thousand board feet. Each stumpage price represents a separate analysis (i.e., stumpage price is constant in any one analysis). Thinnings and final harvests use the same value per thousand board feet. Forage, both natural and planted, is valued at zero, $0.70, $1.25, $2.50, $3.75, and $4.50 per animal unit month in separate analyses. However, values of zero through $1.25 receive the most attention as they more closely represent current and expected forage charges on National Forests.

Nonmarket considerations, such as soil stabilization benefits from planted forage, the social costs associated with smoke from slash burning, esthetics, and the effects on wildlife habitat, all vary with the management regimes but are not included in the present analyses. However, we recognize that occasionally nonmarket considerations may outweigh the economic factors and become the determining influence in a decision.

RESULTS

RETURNS FROM TIMBER

Economic returns from timber, in stands that were precommercially thinned at age 47 years and from control stands, are determined by assuming that all other forest resources are nonmarketable products. In the timber analysis, it is assumed no forage is planted. Natural forage is ignored because we are concerned with differences among management alternatives; natural forage is assumed constant.

In general, thinning stands with 2,300 stems per acre to stocking levels of 250, 125, or 62 stems per acre, is unattractive when judged only on economic returns from timber. This is shown in table 2 (column 5) where *PNW* values (based on a 5-percent discount rate) are negative for every management regime following precommercial thinning; i.e., all regimes earn less than 5 percent on funds invested in precommercial thinning.

PNW values in tables 2 and 3 represent the marginal returns associated with funds invested in each thinning regime. These values were determined by subtracting the present net worth of the appropriate control stand from the present net worth of each thinning regime. A negative *PNW* value for a management regime represents the amount of dollars we would lose per acre by investing in that regime if carrying charges on investments were 5 percent each year.

Present net worth values in table 2 are based on our most optimistic stumpage price ($40 per thousand board feet and a precommercial thinning cost of $22 per acre). When the latter was reduced to $16.50 per acre and when the "Tomahawk" was used to treat slash instead of the machine piling and burning operation, the result was a negligible increase in the economic return.

RETURNS FROM TIMBER AND FORAGE

Economic returns from timber and

Table 2.--Timber yields and present net worth from timber for 10 management regimes

Ranking (based on present net worth)	Management regime	Stocking (after initial thinning)	MAI 1/	Present net worth 2/
		Trees per acre	*Board feet*	*Dollars*
1	Clearcut at age 77 years	62	67	-15.16
2	Clearcut at age 97 years	125	152	-17.48
3	Shelterwood	62	126	-18.84
4	Shelterwood	125	154	-19.15
5	Clearcut at age 77 years	125	75	-19.46
6	Clearcut at age 97 years	62	115	-19.59
7	Clearcut at age 97 years	250	132	-40.06
8	Shelterwood	250	133	-40.19
9	Clearcut at age 77 years	250	52	-52.05
10	Clearcut (noncommercial) at age 47 years and plant new stand	--	0	-59.23

1/ Mean annual increment in present rotation.

2/ PNW values are based on a 5-percent discount rate and reflect the PNW of various regimes after precommercial thinning less the PNW of the appropriate control regime.

forage in stands precommercially thinned at age 47 years, and from control stands, assume forage was planted immediately after precommercial thinning.

Timber and forage returns from thinned stands are greater than those earned by timber only, but they are still less than the guiding rate of return (see column 5, table 3, where no regime has a positive *PNW* value when the discount rate is 5 percent). Note that the four highest ranking regimes based on *PNW* of timber and forage (table 3, column 5) are also the highest ranking regimes in table 2 which is based on timber only. These returns are determined by using a stumpage value of $40 per thousand board feet, one of the higher forage values ($1.25 per animal unit month) presently found on National Forests in the pine-grass region (*13*), and a precommercial thinning cost of $22 per acre. Reducing the precommercial thinning cost to $16.50 per acre has a negligible effect on the returns.

IMPACT OF THE ALLOWABLE CUT EFFECT

The allowable cut effect was defined earlier as "the immediate increase in today's allowable cut which is attributable to expected future increases in yields." Schweitzer et al. (*16*) discussed some of

Table 3.--Timber and forage yields and present net worth from timber and forage for 19 management regimes with and without the allowable cut effect

Ranking[1/]	Management regime	Stocking after initial thinning	Planted forage	Present net worth[2/]		MAI[3/]	Annual forage production
				Without ACE	With ACE		
		Trees per acre		*-------Dollars-------*		*Board feet*	*AUM's*
1	Clearcut at age 97 years	125	yes	-6.36	111.90	152	1.0
2	Clearcut at age 77 years	62	yes	-7.28	37.20	67	1.0
3	Shelterwood	62	yes	-7.54	76.42	126	1.0
4	Shelterwood	125	yes	-7.85	99.97	154	1.0
5	Clearcut at age 97 years	62	yes	-8.47	69.52	115	1.0
6	Clearcut at age 77 years	125	yes	-11.59	40.11	75	1.0
7	Clearcut at age 77 years	62	no	-11.99	32.50	67	[4/].3
8	Clearcut at age 97 years	125	no	-13.57	104.69	152	[4/].3
9	Shelterwood	62	no	-14.86	68.91	126	[4/].3
10	Shelterwood	125	no	-15.20	92.43	154	[4/].3
11	Clearcut at age 97 years	62	no	-15.65	62.33	115	[4/].3
12	Clearcut at age 77 years	125	no	-16.32	35.38	75	[4/].3
13	Shelterwood	250	yes	-28.89	60.38	133	1.0
14	Clearcut at age 97 years	250	yes	-28.94	67.86	132	1.0
15	Clearcut at age 97 years	250	no	-36.92	59.88	132	[4/].25
16	Shelterwood	250	no	-37.02	52.05	133	[4/].25
17	Clearcut at age 77 years	250	yes	-44.18	-12.63	52	1.0
18	Clearcut at age 47 years[5/]	--	--	-47.43	--	0	--
19	Clearcut at age 77 years	250	no	-49.47	-17.93	52	[4/].25

1/ Based on present net worth (PNW) without allowable cut effect (ACE).

2/ Present net worth values are based on a 5-percent discount rate and reflect the PNW of various regimes after precommercial thinning less the PNW of the appropriate control regime.

3/ Mean annual increment in present rotation.

4/ Natural forage yields reach this level by the 10th year after the release of the stagnated stand and then level off.

5/ Clearcut stagnated stand (noncommercial) at age 47 years and plant a new stand.

the physical and economic ramifications of the allowable cut effect and listed the following items to define the decision-making situation that is necessary for an allowable cut effect to occur.

1. The forest manager must calculate an allowable cut and must actually harvest that volume.

2. The allowable cut must be based on volume regulation.

3. The allowable cut must be dependent upon the rate of growth of trees in the management unit.

4. There must be available a reserve of merchantable timber.

One might ask, "Why should we consider the allowable cut effect in this analysis?" This question can be answered best by restating the purpose of this paper: to develop management guidelines for allocating a budget *within* the constraints of a regulated harvest--which is certainly the case where the allowable cut effect is relevant. The allowable cut effect is relevant to the present management of National Forest land in the pine-grass region--the allowable cut is dependent on the rate of tree growth and is normally based on volume regulation, there is an abundance of mature timber available for harvest, and there is usually no problem marketing the timber offered for sale. Hence, if additional timber were rationalized for harvest by the allowable cut effect and if it were offered for sale, no problem in marketing it would be expected.

How is the "immediate increase in today's allowable cut" applied in stands like those described in this study? Consider, for example, a 47-year-old ponderosa pine stand with 2,300 stems per acre. Without management, this stand would yield about 3,200 board feet per acre in 50 years. Many nontreated sapling stands with this approximate age (47 years) and yields (3,200 board feet at rotation age) are included in data used to calculate the present allowable cut. If this stand is precommercially thinned to 125 stems per acre at age 47 years and commercially thinned to 90 stems per acre at age 77 years, it would yield about 14,740 board feet per acre at the end of the rotation--a gain of 11,540 board feet over 50 years.

If the allowable cut effect is recognized, instead of waiting 50 years and then absorbing all of the increase in 1 year, the expected gain is spread equally over 50 years. Therefore, the allowable cut effect for *each* year remaining in the present rotation would be approximately 230 board feet (11,540 board feet per 50 years) for *each* acre of stagnated forest that was brought under management.

On a cash flow basis, if we value stumpage at $40 per thousand board feet, this allowable cut effect of 230 board feet per year for 50 years is the same as an annuity of $9.20 (=$40 x 0.230) for the same period for each treated acre. The result of adding such an annuity to the economic analysis of joint returns is evident in table 3, by comparing columns 5 and 6.

RETURNS FROM FORAGE AND TIMBER WITH THE ALLOWABLE CUT EFFECT

When the allowable cut effect is included in the economic analysis of timber and forage yields, returns from nearly three-fourths of the management regimes exceed the guiding rate of return (table 3, column 6). The highest return is earned by a clearcut regime with 125 stems per acre (after precommercial thinning) that is commercially thinned at age 77 years and clearcut at age 97 years. Returns from all regimes are based on $40-per-thousand-board-foot-stumpage, $1.25-per-AUM-forage, and a precommercial thinning cost of $22 per acre.

When the cost of the precommercial thinning is reduced to $16.50 per acre, the returns from all regimes increase negligibly.

In this analysis, the allowable cut effect--the immediate increase in annual allowable cut--results from the expected future increase in yields that are attributed to the precommercial thinning of the overstocked stands.[7/]

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[7] In 1966, Flora (6) described the effect on allowable cut that results from precommercial thinning in ponderosa pine stands.

The influence of the allowable cut effect on economic returns from investments in thinning these overstocked stands is apparent in figure 8 and in columns 5 and 6 of table 3.

Clearcuts at age 77 years are always low-ranked regimes when the allowable cut effect is considered. Note that a precommercial thinning to 250 trees per acre followed by a clearcut in 30 years (age 77 years) produces a smaller return when the allowable cut effect is not included than clearcutting the stagnated control stand at either age 77 or 97 years (see column 5 in tables 2 and 3). This occurs because the discounted value of the increased growth, in the 30 years following the precommercial thinning, is less than the cost of the precommercial thinning which is incurred immediately and cannot be discounted.

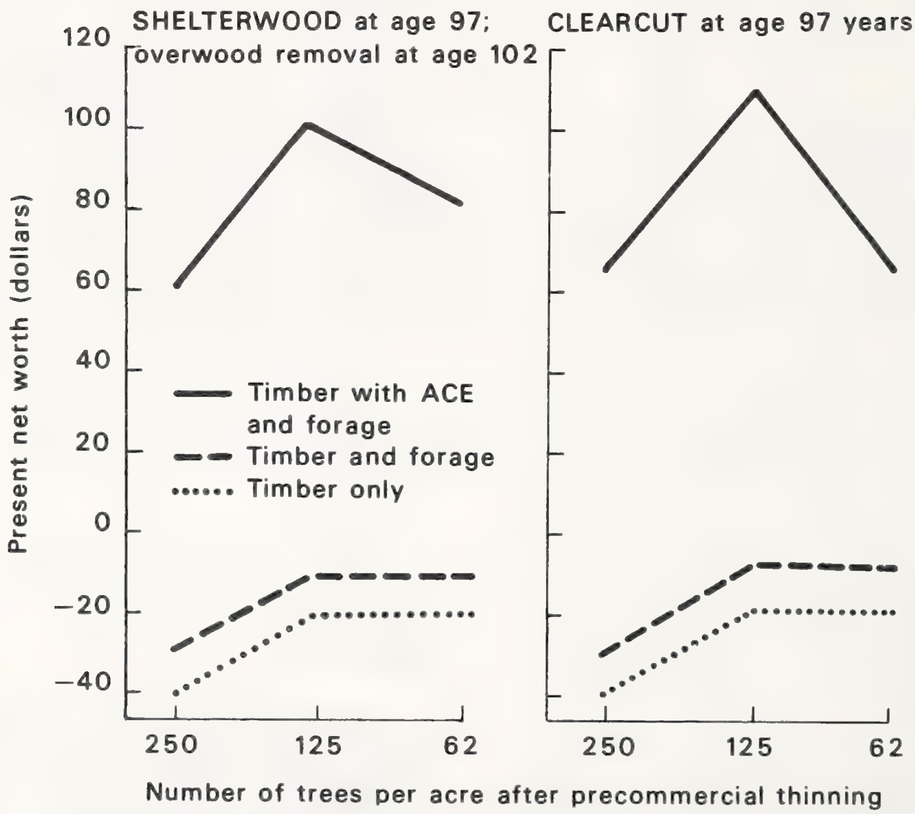

Figure 8.—Present net worth based on a 5-percent discount rate for a shelterwood regime and a clearcut regime for timber, timber and forage, and forage and timber with the allowable cut effect at three stocking levels.

SUMMARY

This analysis is a "first step" approach to thinning guides. It is limited to stagnated sapling stands; however, it points out the need for further research on this topic.

Management regimes have been ranked by their economic returns from timber and timber and forage, with and without the allowable cut effect (tables 2 and 3). What can we learn from these rankings? Are they a positive step in the development of thinning guides for the overstocked ponderosa pine stands? Several points stand out.

PRECOMMERCIAL THINNING ATTRACTIVE INVESTMENT WHEN THE ALLOWABLE CUT EFFECT IS APPLICABLE

Economic returns from funds invested in precommercial thinning easily exceed the guiding rate of return (5 percent) when the allowable cut effect is applicable. When the allowable cut effect is not included, funds invested in precommercial thinning earn less than the guiding rate of return.

BEST ECONOMIC RETURNS FROM 125 TREES PER ACRE

Of the three stocking levels (250, 125, and 62 trees per acre), the 125-trees-per-acre level generally produces greater economic returns than the 250- or the 62-trees-per-acre level. This is especially true when the allowable cut effect is considered. When it is not considered, the 125- and 62-trees-per-acre stocking levels exhibit similar economic returns. However, this does not mean that 125 trees per acre is the most desirable level of stocking. Some untried (in this analysis) stocking level on either side of this level may produce greater joint returns from timber and forage, either with or without the allowable cut effect.

LOWEST ECONOMIC RETURNS FROM 250 TREES PER ACRE

The 250-trees-per-acre level consistently produces lower economic returns than the other two levels. Apparently, this stocking level is still too heavy to produce substantial growth response from a stagnated stand.

CLEARCUTS RANK HIGHER THAN SHELTERWOOD CUTS

In general, economic returns from clearcut regimes rank higher than shelterwood cuts in stands with similar stocking both with and without the allowable cut effect. However, the best shelterwood regime ranks a close second to the best clearcut regime. When the allowable cut effect is considered for regimes with 125 trees per acre, both with and without planted forage, the clearcut (at age 97 years) regime produces the greatest return on investment, followed by the shelterwood regime.

PLANTING FORAGE INCREASES JOINT ECONOMIC RETURNS

Planting forage increases joint economic returns from timber and forage. The amount of increase, both without and with the allowable cut effect, can be seen in table 3, columns 5 and 6. For example, compare rankings number 1 and 8, which are the same except that one has planted forage. Without the allowable cut effect, planting forage increased *PNW* (assuming a 5-percent discount rate) from \$-13.57 to \$-6.36, and with the allowable cut effect, from \$104.69 to \$111.90. Likewise, compare rankings 2 and 7, 3 and 9, 4 and 10, etc.

Do these increases in *PNW* mean that planting forage "pays" or are they negligible? The decision hinges on a marginal analysis of the costs and returns associated with the planting and utilization of forage as outlined elsewhere by Sassaman (*15*). Therefore, in the present study, one may conclude that the returns from forage exceed the cost of planting forage (assuming a 5-percent discount rate), but one cannot make a decision as to how well planting forage "pays" without a marginal analysis of the costs and returns associated with planting forage.

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KEYWORDS: Ponderosa pine, forestry business economics, thinning (trees), allowable cut.

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